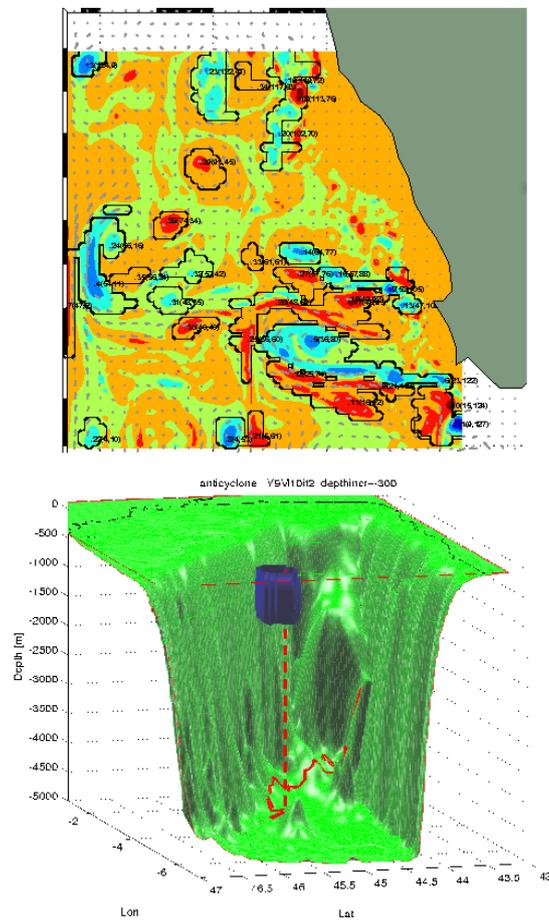


Users Guide for WATERStools

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WATERStools download web site : <http://mio.pytheas.univ-amu.fr/~doglioli>.



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1 Introduction

This guide presents the WATERStools package of Matlab routines, designed for identifying and tracking three-dimensional eddy structures with an objective method in order to evaluate their properties and the water mass they transfer.

Several methods have been proposed for the identification and tracking of mesoscale structures in the ocean circulation. Indeed, mesoscale eddies are ubiquitous features in the world's oceans, and they play a major role in ocean circulation as well as in heat and mass transport. They can have a profound influence on biological productivity, upper ocean ecology and biochemistry, and thus in elemental cycling fluxes (McGillicuddy et al., 1998). The Pyrings method described in Guilherme P. Castelão (2013) is based on the novel objective technique to identify ring center; the authors correct the velocity field by the translation movement to isolate the swirl related dynamics. This method is based on physical properties. One of the most popular methods of this group is based on the Okubo-Weiss parameter: this parameter is computed from the horizontal velocity field. An other method based entirely on the geometry of the velocity vectors of the flow field is presented in Souza et al. (2011) and Nencioli et al. (2010). Our tracking method is inspired on the work of Siegel and Weiss (1997) and based on the wavelet analysis of modeled relative vorticity. Indeed, wavelets form an efficient basis set for localized structures such as ocean eddies.

WATERS project (Wavelet Analysis for Time-tracking Eddies in Regional models, 2004-2006) was designed to study oceanographic eddies simulation in regional ocean models. The main goal of the project was to propose objective tools for identification and tracking of three-dimensional coherent structures. Wavelet analysis allowed us to follow eddies in space and time as long as they exist as coherent structures in the model and to evaluate their translational velocity, diameter, volume and derived parameters.

To accomplish this task and to treat the data, we developed the software collected in the WATERStools package. The software is equipped with a series of graphical and user-friendly accessories and the entire package for Matlab can be freely downloaded from <http://mio.pytheas.univ-amu.fr/~doglioli>.

This is just a basic users guide; details of the wavelet analysis method are described in Doglioli et al. (2007).

2 Installation

2.1 System and software requirements

This toolbox has been designed for Matlab. It needs at least 32 Mbytes of disk space. It has been tested on several Matlab versions ranging from R2006a to R2011b. It has been mostly used on Linux workstations, but also on Windows (windows 8).

The necessary Matlab toolbox *m_map*, *ROMStools*, *Wavelab850* and other free programs are included.

A dataset is also included for running the tutorials described below.

2.2 Getting the files

The entire package WATERStools can be freely downloaded from

<http://mio.pytheas.univ-amu.fr/~doglioli/waterstools.htm>.

The package WATERStool is a free software. It is distributed in the hope that it will be useful, but without any warranty. You can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation at <http://www.gnu.org/copyleft/gpl.html>.

2.3 Extracting the files

Uncompress and untar the file (`gunzip` and `tar -xvf`). You should obtain the following directory tree :

```
WATERS_data_example
WATERStools_0.0
|- Wavelab850
|- M_PACK
|- ROMSTOOLS_v3.1_03_02_2014
|- Documentation
|   |- Userguide
|- Figures
|- fichiers.m
```

Definition of the different directories:

- *WATERS_data_example*: includes a monthly-output file obtained from the Roms_Agrif simulation (website: <http://www.romsagrif.org>); the used setup corresponds to the model of the Southern Benguela at high resolution;
- *Wavelab850*: WaveLab is a collection of Matlab functions that have been used by the authors and collaborators to implement a variety of algorithms related to wavelet analysis (issued from <http://statweb.stanford.edu/~wavelab/>);
- *M_PACK*: is a matlab package including utilities from harmonic analysis of series to a plot of a simple arrow. Moreover, many functions are related with the manipulation of NetCDF data. It has been included for a 3D visualization of eddies identified and tracked by wavelet analysis (website: http://www.odyle.net/mma/archive/m_pack);
- *ROMSTOOLS_v3.1_03_02_2014*: Series of tools for the pre- and post-processing of oceanic regional ROMS simulations issued from <http://www.romsagrif.org>. Furthermore this directory contains the *m_map* package corresponding to a set of mapping tools issued from <http://www.eos.ubc.ca/~rich/map.html>;
- *Documentation*: WATERStools Users Guide with its L^AT_EX source files;
- *Figures*: default folder for graphic outputs;
- *fichiers.m*: scripts files;

3 Fonctionning

3.1 Functioning principles

The identification technique developed is based on the wavelet analysis of modeled relative vorticity. The method to identify three-dimensional structures can be decomposed in three steps, i) the wavelet analysis, it consists in the decomposition of a signal under study into orthogonal, multiresolution wave packets in a way similar to Fourier decomposition. Here, the wave packets are used to decompose successive horizontal map of relative vorticity and to extract localized structure in space; ii) time tracking, at each step of the analysis, the instantaneous translational velocity and the diameter of each coherent eddy are both recorded. Moreover, we checked that both tracking directions led to very comparable results. Thus an eddy identified at a specific instant is tracked both backward and forward in time; iii) vertical tracking, the analysis is repeated at several depths to diagnose the

vertical extent of an eddy. The analysis is started at -200m to eliminate the model surface layers liable to be affected by a dynamics that is too sensitive to air-sea interactions.

The knowledge of instantaneous velocity, diameter and volume of each structures enables one to calculate an instantaneous transport and an instantaneous momentum.

3.2 Future plans

Tracking techniques based on the calculation of Lagrangian trajectories also exist. Such Lagrangian computations coupled with the wavelet-based definition of each eddy volume would be used to calculate the remote origins and fate of the water carried out by each structure. Heat and fresh water transport estimates will also be derived for each eddy.

4 Tutorial : running the demo

The WATERS project contains a demo. Before running the demo, you have to set new path from Matlab. Choose "add with subfolders" and select in the directory tree, i) *ROMSTOOLS_v3.1_03_02_2014*, ii) *Wavelab850*(Fig. 1);

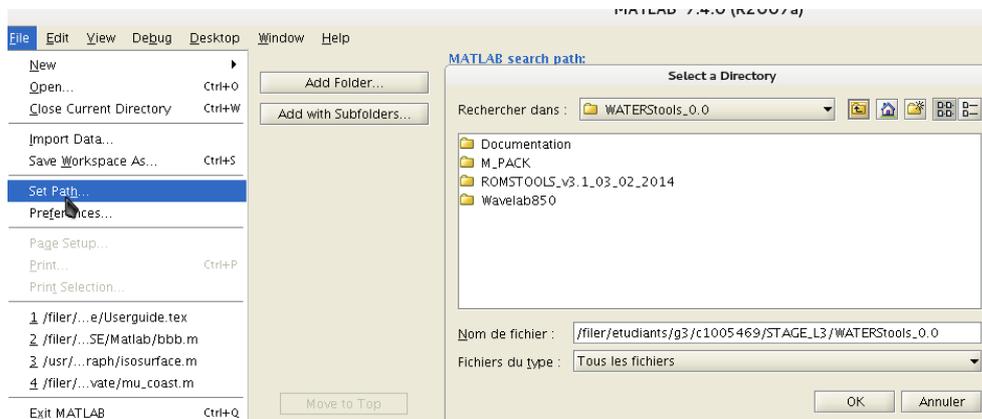


Figure 1: Matlab navigation screen.

iii) in the folder *M_PACK*, select *mfiles* and add the subfolders *roms* and *toolsnc*(Fig. 2).

- 📁 /filer/etudiants/g3/c1005469/STAGE_L3/WATERStools_0.0/M_PACK/m_files/roms
- 📁 /filer/etudiants/g3/c1005469/STAGE_L3/WATERStools_0.0/M_PACK/m_files/roms/roms_ncep
- 📁 /filer/etudiants/g3/c1005469/STAGE_L3/WATERStools_0.0/M_PACK/m_files/roms/roms_series
- 📁 /filer/etudiants/g3/c1005469/STAGE_L3/WATERStools_0.0/M_PACK/m_files/roms/roms_slice
- 📁 /filer/etudiants/g3/c1005469/STAGE_L3/WATERStools_0.0/M_PACK/m_files/toolsnc

Figure 2: Subfolders added from *M_PACK*.

To start the demo, run *tracking3d_ini.m*. The current velocity vectors, the relative vorticity and the coastline of a small portion of the Cape Basin should be represented (Fig. 3).

You can choose the eddy to tracking by right clicking with the mouse on the map. The left click informs you about the localization, the center and the sign of the eddy. A dialog box asks you at each step of the analysis if you want to continue the eddy's tracking. If you want to stop it, click "No". If not, the tracking begins. As we saw in the section '**Functionning principles**' the demo begins with the wavelet analysis, then, the time tracking and in last, the vertical tracking. In the following, MATLAB figures will save in the *WATERtools_0.0* figures. One figure is recorded for each interval and for each specifications. The demo takes about 4-5 minutes, depending on your rapidity on aswer to dialog boxes and on the performances of your computer.

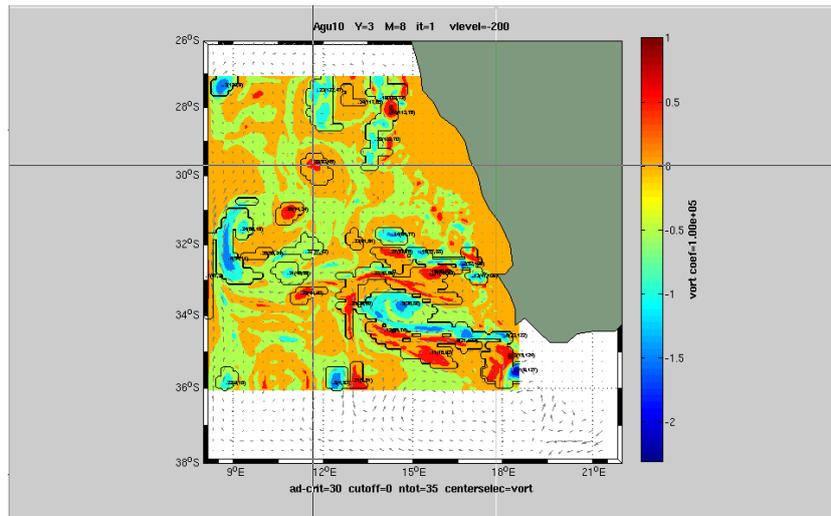


Figure 3: First figure of the demo. Current velocity vectors and the coastline are shown. The black lines represented the periphery of each eddy as identified by the first wavelet analysis. The color represents the intensity of vorticity. In our simulation the tracking eddy chosen is under the pointer.

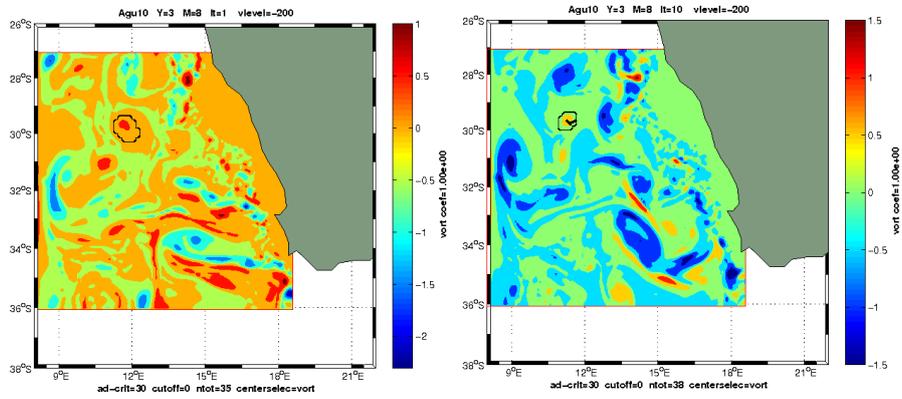


Figure 4: Current velocity vectors and the coastline are shown. The dotted line (right) represents displacement of the eddy after 10 iterations.

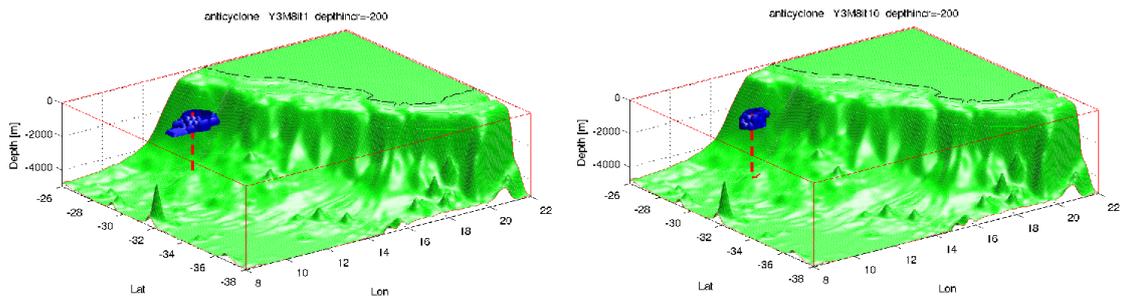


Figure 5: First and final figures of 3D eddy time-tracking. It shows us the displacement and the stretching of the eddy.

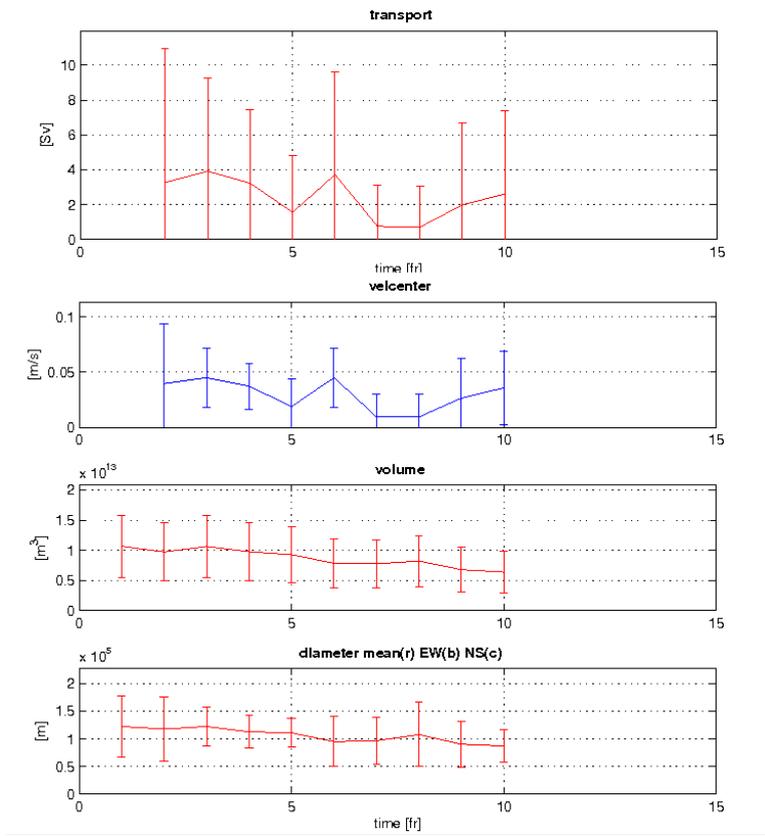


Figure 6: top to bottom: instantaneous transport, translational velocity, volume and diameter of the eddy.

In the previously, we recall that all fields are calculated on month 8/ year 3,
MATLAB (Fig. 4): Time tracking is represented ;
MATLAB (Fig. 5): Vertical tracking is represented and shows us the displacement
of the eddy. The dotted line represents the center of the eddy;
MATLAB (Fig. 6): shows different periods in the life of the eddy. When the eddy
moves over the continental slope, its translational velocity is weak, and its shape
is more or less circular. The successive growth and reduction of its volume as well
as a high variability of its diameter indicate that it incorporates and loses some
mass.

4.1 Warnings

For a faster demo, some parameters have unrealistic default values:

- the number of interval (called itmax) has only 10 steps.
- the dimension of the area of research (called delta) has also been adapted to the demo, to provide a clearest modelisation.

Of course, you can modify these values. All the parameter for the demo are regrouped in *parameters3d.m* script.

Conversely, some parameters could slow the demo as for example :

- the dialogbox, you can comment lines included in file *anim_tracking3d.m*
- the display of Fig. 5 and Fig. 4, you have just to replace `figure('Visible','on')` by `figure('Visible','off')` in files *print3d_2.m* and *print3d_4.m* to prevent it.

References

- Doglioli, A. M., Blanke, B., Speich, S., and Lapeyre, G. (2007). Tracking coherent structures in a regional ocean model with wavelet analysis: application to Cape Basin Eddies. *J. Geophys. Res.*, 112.
- Guilherme P. Castelão, Luiz C. Irber Jr., A. B. M. V. B. (2013). An objective reference system for studying rings in the ocean. *Computers & Geosciences*, 61(0):43 – 49.
- McGillicuddy, D., Robinson, A., Siegel, D., Jannasch, H., Johnson, R., Dickey, T., McNeil, J., Michaels, A., and Knap, A. (1998). Influence of mesoscale eddies on new production in the Sargasso Sea. *Nature*, 394:263–266.
- Nencioli, F., Dong, C., Dickey, T., Washburn, L., and McWilliams, J. C. (2010). A vector geometry-based eddy detection algorithm and its application to a high-resolution numerical model product and high-frequency radar surface velocities in the Southern California Bight. *J. Atmos. Ocean. Technol.*, 27:564–579.
- Siegel, A. and Weiss, J. B. (1997). A wavelet-packet census algorithm for calculating vortex statistics. *Physics of Fluids*, 9:1988–1999.
- Souza, J. M. A. C., de Boyer Montégut, C., and Le Traon, P. Y. (2011). Comparison between three implementations of automatic identification algorithms for the quantification and characterization of mesoscale eddies in the south atlantic ocean. *Ocean Science*, 7(3):317–334.